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DETERIORATION of SUGAR MAPLE following logging damage

by

Gene A. Hesterberg

LAKE STATES FOREST EXPERIMENT STATION
M. B. Dickerman, Director
FOREST SERVICE,
U.S. DEPARTMENT OF AGRICULTURE

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Gene A. Hesterberg[2/]

INTRODUCTION

The northern hardwood forest comprises about 9 million acres in the Lake States region. Most of this timber is in Upper Michigan and Wisconsin, with lesser amounts in Minnesota. It consists primarily of sugar maple (*Acer saccharum* Marsh.), yellow birch (*Betula alleghaniensis* Britt.), basswood (*Tilia americana* L.), and often eastern hemlock (*Tsuga canadensis* (L.) Carr.). Although yellow birch is of considerable economic value in this forest type, it is secondary in importance to sugar maple.

Only a small part of the area is in old-growth forest, and at the present rate of cutting these stands will soon disappear. However, many tracts of saplings that developed after early logging operations have grown to pole size and now constitute an important area of near-merchantable sawtimber (3).[3/] In addition, some areas have been logged on a partial-cut system, leaving rather extensive reserve stands. This system is being applied to a progressively greater extent each year.

1/ This study was conducted by the Lake States Forest Experiment Station on a cooperative basis with the Laboratory of Pathology in Forest Practice, School of Natural Resources, University of Michigan, and the Michigan College of Mining and Technology. The Lake States Station is maintained by the Forest Service, U. S. Department of Agriculture, at St. Paul 1, Minn., in cooperation with the University of Minnesota.

2/ Assistant Professor of Forestry at the Michigan College of Mining and Technology. Dr. Hesterberg was employed by the Station on a temporary basis to make this study. Acknowledgment is due Dr. Dow V. Baxter, University of Michigan, who provided invaluable guidance in the conduct of the fieldwork and preparation of the manuscript.

3/ Figures in parentheses refer to Literature Cited on page 30.

In sustained-yield management the partial-cutting method is currently held to be the most desirable one for maintaining hardwood forests in continuous sawlog production and at the same time providing for improvement of log quality and log grade.[4] It provides for periodic removal of a volume equivalent to the net growth of the forest. The ultimate objective is the development of a well-stocked, uneven-aged forest, allowing harvests of about equal size to be made at relatively short intervals. This is the "Selection System"[5] as defined by the Society of American Foresters' Committee on Forestry Terminology.

Partial cutting, however, may have some disadvantages, one of which is the subject of this study. It has been demonstrated that use of this system in logging hardwood forests will unavoidably injure certain trees of the reserve stand (6). Furthermore, preliminary observations at the Upper Peninsula Experimental Forest at Dukes, Mich., indicated that about one-third of the logging-scarred trees develop butt rot or other defect within 20 years. However, little is known about the relation of logging wounds to eventual deterioration of residual trees. Can forest owners leave logging-scarred timber in the reserve stand without excessive loss from decay? What is the rate of decay caused by fungi that can be traced to logging scars? Answers to these important questions are needed to provide a better evaluation of the effect of logging damage in partially cut northern hardwood forests of the Lake States. Others of importance are: What fungi are responsible for the most extensive defect following logging injury? Do logging wounds affect log volume and lumber grade recovery?

Recent recommendations for the practice of sustained-yield management in the northern hardwood forest and the current trend towards increased mechanization with heavy equipment in the logging industry certainly justify an appraisal of the effect of mechanical injuries to the trees of the residual stand.

This report presents the results of an investigation into the nature and extent of defect that can be traced directly to skidding and felling injuries to trees of the reserve forest. The study was confined to sugar maple, a species of high commercial value and the most important component of the northern hardwood type. Attention was

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4/ Advantages often cited include: Rapid growth stimulation of submerchantable trees, reduction of windthrow in the stand to a minimum, and maintenance of reproduction of desirable species for the perpetuation of an uneven-aged forest.

5/ Removal of mature timber, usually the oldest or largest trees, either as single scattered trees or in small groups at relatively short intervals, commonly 5 to 20 years, repeated indefinitely, by means of which the continuous establishment of natural reproduction is encouraged and an uneven-aged stand is maintained (10).

directed to measurement of the losses caused by decay and stain fungi that may become established at injuries. Furthermore, an estimate was made of losses caused by rot in standing wounded trees over a period of time or for the length of the cutting cycle. Sugar maple logs were dissected at a mill to provide this information and to determine the influence of logging wounds on lumber grade recovery.

PREVIOUS REPORTS OF LOGGING DAMAGE

The effects of logging damage to residual hardwood stands have been little explored. Some accounts have been published concerning logging damage to coniferous forests, but the ultimate losses caused by decay and stain fungi have been considered for only a few of our commercially important softwoods (5).

In spruce-fir stands of northeastern United States Westveld recorded 18 percent of the reproduction and growing stock damaged or destroyed as a result of logging injuries (19). Another study in that region by Trimble showed that logging damage in second-growth spruce-fir pulpwood stands is not a deterrent to partial cutting when carried out with horse logging (18).

Much decay in western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) following logging injury was reported by Englerth and Isaac (5). Theirs was the first systematic attempt to disclose the extent of decay resulting from wounds made during partial-cutting operations in Douglas-fir--western hemlock stands. They found 304 scars on 654 residual trees from an area that had been logged 12 years previously; 57 percent of the scars were either discolored or decayed. It was concluded that wood-destroying fungi induced considerable cull in scarred logs. Since the majority of their sample trees had basal injuries, cull in the more valuable butt log occurred most frequently.

Comparable studies of the effects of logging damage to residual hardwood stands have never been made. Ostrom gives a brief account of defects that might be expected after timber stand improvement work in a young birch-beech-maple-hemlock type of the Northeast (16). Approximately 46 percent of the sugar maples were partly defective, but only 6.5 percent of the trees had minor bark injuries or mechanical bark wounds attributable to logging damage.

A study of logging injury incident to skidding in partly cut northern hardwoods was made by Engle in Upper Michigan (4). The frequency and severity of injuries to trees on an area skidded with D-2 tractors were compared with wounds incurred on an area skidded with teams of horses. Engle concluded that tractor skidding injures more small

hardwoods (2 to 9 inches in diameter at breast height) than horse skidding but that there is no great difference in the amount of damage to residual trees in the larger diameter classes. These data, although not conclusive, indicate that, when carefully supervised, tractor logging need be no more injurious to the residual stand than horse logging.[6/]

The frequency of injury caused by logging with heavy equipment in the selection forest likewise is poorly understood (fig. 1). Hooker compared data on logging injuries incurred in northern hardwoods in the Upper Peninsula by arch skidding tree-length units and by ground skidding log lengths by tractor (13). Tree-length units were skidded with an Allis-Chalmers HD-5 tractor with a $10\frac{1}{2}$-foot bulldozer blade pulling a Carco-type sulky. The log-length units were skidded by an Allis-Chalmers HD-5 tractor equipped with three sets of skidding tongs. The tree-length method produced more stem scars per skidding turn and resulted in considerably larger mechanical wounds. However, the majority of the injuries occurred higher on the butt log, and there were fewer wounds per thousand board-feet of logs harvested than occurred with conventional log-length skidding methods.

The significance of scar size and location on the bole has never been determined. If the wounds become infected by decay-producing fungi, the net increment on the injured trees that continue to live and grow will be decreased and the advantages of partial cutting will be reduced greatly.

OBJECTIVES OF THE STUDY

The chief reason for leaving reserve trees in partial cutting is to provide established growing stock for the future. These may be considered "risk trees" in the sense that they could be harvested and converted into profit immediately. Reserve trees usually are expected to accelerate in growth rate; they are exposed, however, to many forms of injury and especially to logging damage and the losses that may accompany it.

It is well known that many wounds caused during logging operations can be avoided. Since the partial-cutting method currently is advocated for harvesting northern hardwood forests in the Lake States, facts concerning the potential effects of logging injury on the reserve stand are needed.

6/ However, tractors with bulldozer blades intact generally should not be used for skidding purposes.

Figure 1.--An HD-5 tractor skidding tree-length "stringers" with a Carco-type arch during a partial cutting operation in Marquette County, Mich. Since a capital investment in young growing stock remains on the land, logging damage to the residual stand must be held to a minimum.

The principal objectives of this study of sugar maple are to determine the following:

1. The length of time required for logging injuries to effect serious losses.

2. A quantitative measure of the fixed and cumulative losses[7] resulting from the cull and degrade associated with logging injuries.

3. The relative susceptibility of different kinds and sizes of wounds to the development of decay and discoloration.

4. The fungi that are primarily responsible for the defects developing at logging injuries, and their relation to the chief types of decay.[8]

5. The correlation of external characteristics of wounds with kinds of fungi that become established and with the rate of decay (9, 15), which could be used as a guide for forest managers in evaluating "risk trees" in reserve stands.

7/ Fixed loss refers to damage that remains static and lowers the lumber grade, such as ingrown bark. Cumulative loss, as used by Meinecke (14), includes both the present amount of rot and the decay volume that accumulates over a given period of years.

8/ This phase of the study is largely omitted from this paper and will be presented as a separate publication.

GENERAL PLAN OF INVESTIGATION

The investigation was conducted on the Upper Peninsula Experimental Forest at Dukes, Mich. The fieldwork included examination of standing timber with logging scars and the dissection of injured trees obtained by relogging old permanent sample plot areas and partial-cutting compartments.

About 19 acres of permanent sample plots suitable for this study were available at the Experimental Forest. Records describing injury to the bole, growth, and merchantable height for individual trees on most of these plots have been taken at 5-year intervals for the past 25 years. All have been partially cut and records maintained on an individual tree basis for all logging injuries sustained in past cuttings.

Logging Wound Classification

Appraisal of losses that may be attributed to logging damage required examining trees with mechanical injuries of known age, felling and bucking these trees into conventional log lengths, dissecting marked sample logs in the sawmill, and determining the extent of volume losses and lumber degrade losses that could be traced to the logging scars.

Living maples on permanent sample plots of the reserve stand were examined to seek specific external signs that could be correlated with evident loss caused by logging damage. Two age classes of wounds were investigated: 10-year-old and 20-year-old scars. Rate of decay was determined by measurement of defective areas in boards sawed from logs of these trees. The fungi associated with the wounds were isolated for later identification . The information gathered on rate of decay was then related to external evidences of defect for possible use in preparing a marking guide for determining "risk trees" of the reserve stand.

To supplement records obtained from these plots, the same information was compiled for maples on several partial-cutting compartments and reserve areas other than those in which the sample plots had been established.

The author's experience, while cruising more than 50,000 acres of partially cut northern hardwood stands in Upper Michigan over a period of years, had indicated three principal types of logging damage: (1) Lower stem scars resulting from removal of bark by mechanical injuries, (2) upper stem scars, and (3) wounds from broken limbs. Wounds of these three types were classified and the number of trees required for dissection determined (table 1).

Table 1.--Number of sugar maple sample trees needed to provide a valid appraisal of losses from the more common types of logging damage[1/]

Type of injury	Age class of injury: 10-year-old scars	Age class of injury: 20-year-old scars	Total
Lower stem scars[2/]			
Probable infection court[3/]	10	10	20
Improbable infection court[4/]	10	10	20
Upper stem scars[5/]			
Probable infection court[3/]	10	10	20
Improbable infection court[4/]	10	10	20
Wounds at broken limbs			
Probable infection court[6/]	18	18	36
Improbable infection court[7/]	17	17	34

1/ The number of sample trees needed was suggested by S. R. Gevorkiantz, Lake States Forest Experiment Station.

2/ Scars in the basal 8-foot log.

3/ Includes all logging scars that, at time of wounding, exposed more than 50 square inches of wood.

4/ Includes all logging scars that, at time of wounding, exposed 50 square inches or less of wood.

5/ Logging scars in logs above the basal 8-foot section, other than limb stubs.

6/ Limb stubs 4 inches and larger in diameter.

7/ Limb stubs less than 4 inches in diameter.

In the classification all stem scars that exceeded 50 square inches were recorded as probable infection areas. Smaller wounds were regarded as less likely centers for infection by wood-destroying fungi. In addition to tallying the amount of scar surface area, width of the broadest place on the wound and length of each scar were measured to see if these factors could be related to frequency or extent of decay when the logs were dissected at the mill.

Wounds caused by branch breakage were considered potential infection courts if the stubs were 4 inches or larger in diameter. Smaller stubs were considered less suitable points for infection in this classification. Special attention was directed to all wounds at broken limbs on the lower part of the crown that might involve the sawlog section of the bole.

Prefelling Survey

The principal purpose of making a survey of standing timber was to insure that sample trees finally selected for dissection would provide an adequate representation in the various categories of logging scars and broken limbs described in table 1, and to observe external evidence of logging damage in standing trees prior to the dissection of logs at the sawmill.

Small logging scars on vigorously growing sugar maples often had completely callused over since the first logging operation. Therefore, the prefelling survey was first completed on injured trees of the permanent sample plots to permit observation of the facial aspect of many different stem scars of known history and age. These sample plot trees provided standards for comparison and valid appraisal of trees on the adjacent areas with known logging history but no individual tree records.

For sugar maple to qualify as a sample suitable for dissection at the mill, certain specifications were considered essential:

1. The tree must be in the merchantable diameter class.

2. The tree must have one or more logging scars or limb stubs.

3. The tree must be free of visible natural defects near the scars that might cause difficulty in determining the losses resulting from logging damage.

Sample trees with 10-year-old logging scars were selected on 2 partial-cutting compartments comprising about 50 acres during the summer of 1953. This tract had been logged for the first time in 1942, but permanent sample plot areas were not available in this age class of cutting. However, since only the smaller logging scars had developed sufficient callus to conceal the nature of the wound area, this did not present a problem, and most of the trees injured during the first logging operation could be identified. Skid trails were still discernible in some places and often yielded evidence of the cause of injury. Furthermore, stump tops were still intact, and these provided signs of the felling direction for certain of the previously harvested trees that had damaged the residual stand. By examining each wounded tree and by noting the surrounding stumps and skid trails, it was possible to obtain the sample needed.

Selection of trees with 20-year-old wounds was made on 51 acres of northern hardwood forest in 3 partial-cutting compartments that had been logged in 1928 and 1930 and were relogged in the summer of 1952.[9/]

9/ Sample trees were taken only from areas logged in 1928 and 1930. Wounds from these trees were classed as 20 years old.

Each of these compartments contained 1 or more acres of permanent sample plots. Examination of the plot records indicated that they would yield approximately 60 percent of the sample trees needed. Since detailed records describing the history of the previous felling operations were available for each partial-cutting compartment, logging injuries to trees on the reserve areas could also be dated. Furthermore, the types of logging on the reserve areas corresponded to those practiced on the permanent sample plots within their respective compartments. Therefore, the remainder of the logging-injured trees needed for dissection were taken from the partial-cutting compartments surrounding the permanent sample plot locations.

Trees selected for dissection were marked, and their positions on the sample plot or reserve area were plotted on a field map to facilitate relocation for felling, bucking, and subsequent field examination. A tally was maintained to record each sample tree by the specific type of injury.

Tabulation of Field Data

Photographs were taken of each sample tree during the prefelling survey. These were made to illustrate the more common types of logging scars and to supplement the descriptions given in the tally forms. A number of these photographs, together with an analysis of cull traced to logging injuries, are presented in Appendix A.

The trees were felled and bucked into logs according to the utilization standards of the sawmill cooperator[10/] and the U. S. Forest Service. All sample logs sent to the mill were identified by serial numbers and letters painted on the ends.

In addition to the photographs of the various types of injuries, the Felled Tree Record form and the Sample Log Record form were filled out for each log (see Appendix B).

Because other investigators had pointed out the difficulties of detecting certain incipient decays in hardwoods (1, 2), special care was taken to include all sections with early decay and advanced rot attributed to old logging injuries. Ends of logs were examined for evidence of decay or discoloration from nearby scars as a precaution against omitting logs with incipient rot. The extent of discoloration[11/]

10/ Fries Brothers sawmill, a small portable mill equipped to saw 8-foot logs. Veneer logs and bowling pin stock, manufactured into products elsewhere, were often bucked into longer lengths.

11/ Discoloration referred to in this paper concerns only that caused by fungi. "Mineral stain" (17), so common in Michigan sugar maple, is not considered in this project.

and ingrown bark was also noted and recorded. If it was evident that the decay was confined to one log, as at small injuries, only the scarred log was dissected at the mill.

The annual rings of callus tissue, which develop after an injury, were counted to make certain that the age of the stem scar agreed with the past logging history of the compartments.

The forms also provided for recording information on the rate and amount of healing of the wounds, the age of the injury, the presence of fungus fruiting bodies, and the evidence of slime flux at the scar. Three main classes of callus formation were considered: (1) Scars completely healed with a tight, smooth-surfaced layer of healthy-appearing callus, (2) scars covered with rough, coarse callus tissue, but with a callus "rib" formed by opposite sides of the wound, and (3) scars with callus present but with part of the wood still exposed and still providing an infection court for fungus attack.

Logs Dissected at the Mill

When logs from the sample trees were placed on the mill carriage the end nearest the head saw was marked to denote the face containing the stem scar or wound at broken limb. Guided by this mark, the observer circled the area of each defect on one surface of each board. He also numbered all boards sawed from the log.

Rough-sawed boards from each sample log were placed on a skid, and a "loose package" of lumber was prepared so that every log was more or less reconstructed of its component boards. Care was taken during this procedure to insure that the lumber was oriented so the extent of decay, discoloration, or ingrown bark could be accurately measured.

All defects were classified as cumulative or fixed losses (see footnote 7, page 5). Since most stain fungi and discoloring agents (except mineral stain) were confined to the immediate wound area, they were considered fixed losses. Some stain fungi, however, induced cumulative losses, and these were classified accordingly.

Data tallied on the Sample Log Record form for cumulative losses resulting from logging injury included: (1) Total length of decay, (2) maximum depth (thickness) of rot into the heartwood, (3) maximum width of decay, and (4) type of decay classified by the effect on lumber; that is, white rot or white rot with black lines.

Measurements of fixed losses (those losses in which the actual damage did not increase with time, but which may result in lumber grade reduction) included: (1) Total length and width of defect area, and (2) depth of defect into the wood.

An outline sketch was also made to illustrate the location of the scar in the face view as it would appear on the log. A longitudinal sketch, in side view, was prepared to illustrate the depth of penetration into the wood; cumulative losses were outlined in red and fixed losses in green.[12/] The lumber was then placed in a separate pile in the air-seasoning yard. The volume loss in cull that resulted from the logging scar was computed, using the standard rule for defect.[13/] In practice, an inch was added to the dimensions of both decay width and thickness as a safety factor to insure including all of the cull volume.

Data on lumber grades were obtained to evaluate the relation of logging injury to the possible reduction in value of the boards sawed from scarred logs and to show the significance of fixed and cumulative losses on lumber grade.

The lumber inspector of the Forest Products Laboratory, Madison, Wis., scaled and graded the boards obtained from the dissected logs to determine the reduction in lumber grade and value caused by the logging injuries. Each board, previously marked in red timber crayon with the identifying sample log record number, was graded for: (1) The actual lumber grade, which was tallied beside the log number, and (2) the lumber grade obtained by assuming there were no defects traceable to logging scars. This latter grade, for the same board, was entered in a separate column in the lumber tally book so that both grades for the same board were shown on the same line with the scale of the plank. The difference between volumes in each grade then would indicate the reduction in lumber quality, if any, resulting from the wounds. Although grade recovery was based on the standard lumber grades for 4/4 green sugar maple, analysis of the effects of logging damage was based on the four units of lumber grades commonly sold to the hardwood lumber-using industry.[14/]

12/ Two specimen boards with decay or stain traced to the logging injury were selected from each sample log. These boards were taken immediately to a nearby field laboratory for the purpose of isolating and determining the decay- or stain-producing organisms present.

13/ Deduction in board-feet =

$$\frac{W \times T \times L}{12} \times \frac{80}{100} = \frac{W \times T \times L}{15},$$ where W is the width of defect in inches, T is the thickness in inches, and L is the length in feet.

14/ Sales of lumber by the hardwood sawmills in the Lake States are commonly based on the following groups of lumber grades: Firsts and Seconds and Selects (referred to in the trade as "Selects and Better"), No. 1 Common, No. 2 Common and No. 3A Common, and No. 3B Common.

Chemical Bolts Dissected

Sections of stems unsuitable for sawlogs and left for chemical bolts were examined for decay in the woods. The extent of rot was measured for the Sample Log Record form, as previously described. If decay or discoloration was noticed in the chemical bolt, the bolt was split lengthwise and the defect traced back to the logging scar or limb stub. The fungi responsible were isolated and cultured for future identification.

ANALYSIS OF LOSSES TRACED TO LOGGING SCARS

The information obtained from dissected trees with 10-year-old scars and with 20-year-old scars was handled in the same manner, thus providing a basis for comparison of cull information for the two age classes. Certain qualitative losses such as sawlog grade reduction caused by old logging scars, however, are influenced by the quality of the original sample trees.

Size-Class Distribution of Sample Trees

The study was confined to sawlog-size trees (except for one maple which was near-merchantable) for two reasons: (1) To determine the extent of heart rot which occurs following logging injury to the more valuable size class of maples, and (2) to determine the effect of logging damage on sawlog quality as well as the cull percent that may be attributed to logging wounds in standing, merchantable trees. The diameter-class distribution of the trees prepared for dissection at the mill is presented in table 2. Only two of the maples had to be discarded because decay originating at the logging scars was masked by extensive rot resulting from other causes.

Extent and Distribution of Injuries

Sample trees with 10-year-old damage had 83 wounds resulting from branch breakage and 157 stem scars (table 3). A total of 45 wounds at broken branches and 106 stem scars occurred on the sample trees with 20-year-old logging scars.

Broken limbs and frayed stubs were generally restricted to the upper part of the merchantable bole and to its major branches. Stem scars, however, were distributed throughout the length of the merchantable bole as well as below stump height. Figure 2 shows the percent of

Table 2.--Diameter-class distribution of sugar maples dissected

Diameter breast high (inches)	Number of sample trees with-- 10-year-old scars	Number of sample trees with-- 20-year-old scars	Diameter breast high (inches)	Number of sample trees with-- 10-year-old scars	Number of sample trees with-- 20-year-old scars
10	--	1	20	4	1
11	1	2	21	1	3
12	7	3	22	2	2
13	2	3	23	3	2
14	9	3	24	--	1
15	10	4	25	1	1
16	4	11	26	--	1
17	4	4	30	1	--
18	3	8			
19	7	6	Total	59	56

stem scars along different sections of the bole for the two age classes of logging injuries. More than one-third of the stem scars examined occurred within 6 feet of the ground.

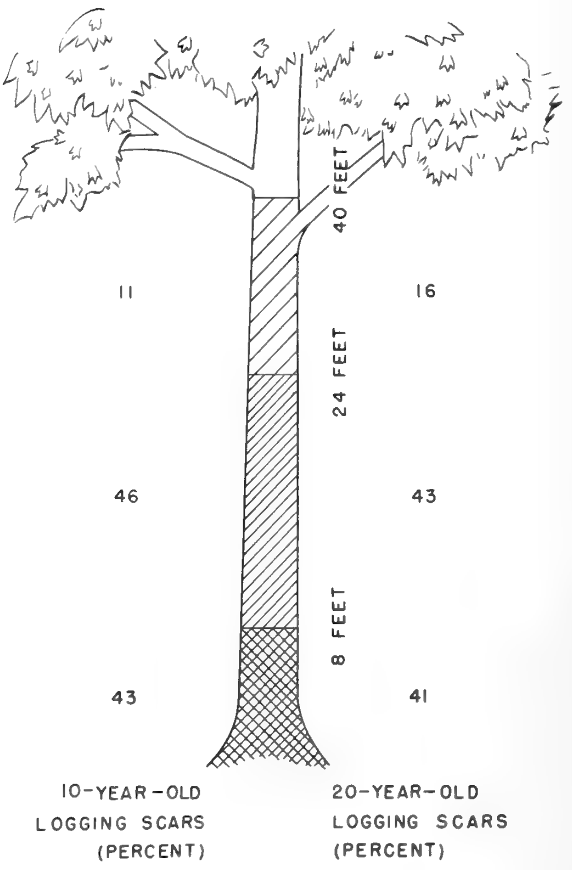

Figure 2.--Frequency of stem scars at different heights on the merchantable bole of the sugar maples dissected. Percentages represent 157 stem scars that were 10 years old and 106 that were 20 years old.

Table 3.--Number of stem scars and wounds from broken limbs in sample logs, by infection court and age of wound

Position of injury	Probable infection court		Improbable infection court	
	10-year-old wounds	20-year-old wounds	10-year-old wounds	20-year-old wounds
Broken limbs	9	11	74	34
Stem scars				
Basal[1/]	34	18	34	25
Upper[2/]	33	25	56	38

1/ Scars in the basal 8-foot log.
2/ Scars in logs above the basal 8-foot log.

Losses Resulting From Decay at Small Branch Stubs[15/]

Sixty-six sawlogs with a gross log scale of 2,190 board-feet had wounds resulting from breakage of limbs less than 4 inches in diameter (improbable infection court). Forty-five of the logs had 10-year-old wounds; 21 had 20-year-old wounds.

Of the 74 wounds at broken limbs that were 10 years old, 72 were free of defect traceable to logging injuries. This was also true for all but 1 of the 34 limb scars 20 years old.

Decay traceable to wounds at broken limbs on 2 of the 74 injuries 10 years old resulted in log scale deduction. Although there was no external evidence of rot, 1 limb stub 2 inches in diameter served as the infection court for *Daedalea unicolor* (Bull.) Fr. This fungus caused a white rot that extended 3 inches into the heartwood. The rot area was 2 inches wide and extended 19 inches longitudinally in the log. The cumulative loss was estimated as 1 board-foot. Likewise, there was no external evidence of decay at a 3-inch-diameter limb stub exhibiting white rot that extended 8 inches into the heartwood and 46 inches in a longitudinal direction. This decay resulted in a loss of 10 board-feet of log scale.

The 1 wound showing decay among the 34 injuries 20 years old was a 3-inch-diameter frayed stub that was almost overgrown with callus tissue. There was no external evidence suggesting presence of decay in the standing tree. The maximum width and depth of decay each measured 2 inches, and the length was 44 inches. A cumulative loss of 3 board-feet in a log with a gross scale of 50 board-feet indicates a negligible amount of damage from a 20-year-old wound.

15/ Injuries occurring on the upper part of the merchantable bole.

In all other logs where branch stubs were less than 4 inches in diameter, no deduction for cull was necessary. Loss in volume caused by decay in logs dissected for this type of defect was less than 1 percent of their gross sawlog volume. Likewise, the cull was negligible (0.14 percent of the sawtimber volume) for the gross volume of standing trees from which the logs were taken.

Losses Resulting From Decay at Large Branch Stubs

In contrast to the relatively low rate of infection among smaller branch stubs, 8 out of 9 logs with 10-year-old large stubs 4 inches or more in diameter showed some defect. The wound at the broken limb on the ninth log was only 4 inches in diameter, the minimum size to be classed as "large." Cumulative losses amounted to 74 board-feet, which was 3 percent of the 2,582 board-feet in the standing trees. The loss thus averaged 8 board-feet per wound for the 10-year period. Sawlog quality was also affected somewhat, since decay caused degrade of 39 board-feet of lumber plus an additional 5 board-feet for 1 plank lost as Mill Cull.

Significant losses occurred in the 11 logs with a gross scale of 470 board-feet, each with a 20-year-old large stub. Defect occurred at all of these large branch stubs, and the amount of cull averaged 19 board-feet. In the 2,686 board-feet of sawtimber from which the logs were cut, wounds at large broken branches resulted in 208 board-feet of cull in 20 years, a cumulative loss of 8 percent.

Losses Resulting From Decay at Stem Scars

The number of stem scars and the percent infection for the two age classes are given in table 4. The data show that frequency of decay was not correlated with scar height on the tree. Size of the original stem scar, however, is a valid basis for judging possible infection during the 10-year or 20-year exposure period.

There is a 50-50 chance that decay will be present in a wound at the end of 10 years when the scar area exceeds 150 square inches (fig. 3). Eighty to one hundred percent of the scars that expose 250 square inches or more of sapwood result in a cumulative type of loss.

For stem scars exposed over 20 years, the frequency of decay is 50 percent when more than 60 square inches of sapwood are exposed, and 80 to 100 percent if 130 to 200 square inches or more are exposed (fig. 4).

Figures 5 and 6 present the least squares relation between scar width and the percent of logging scars with decay. For the data derived from dissection of logs with 10-year-old stem scars, a coefficient of correlation squared (r^2) of 0.922 was computed. This indicates that

Table 4.--Percent of 10-year-old and 20-year-old stem scars that are infected

Infection court and position of scar	10-year-old wounds: Total	10-year-old wounds: Scars with decay		20-year-old wounds: Total	20-year-old wounds: Scars with decay	
	Number	Number	Percent	Number	Number	Percent
Probable infection court[1]						
Basal[2]	34	18	53	18	15	83
Upper[3]	33	21	64	25	18	72
Improbable infection court[4]						
Basal[2]	34	0	0	25	3	12
Upper[3]	56	1	2	38	3	8
Total	157	40	--	106	39	--

1/ Includes all logging scars that, at time of wounding, exposed more than 50 square inches of wood.

2/ Scars in the basal 8-foot log.

3/ Scars in logs above the basal 8-foot log.

4/ Includes all logging scars that, at time of wounding, exposed 50 square inches or less of wood.

about 92 percent of the incidence of decay can be explained by the original width of the scar. Over 50 percent of the stem scars show decay when logging scar width exceeds 7 inches (fig. 5). Scars 11 inches wide result in a cumulative loss in over 90 percent of the cases.

Similarly, stem scar width was related to decay occurrence for 20-year-old logging injuries: an r^2 of 0.796 was computed, indicating that about 80 percent of the incidence of decay can be explained by the original width of the wound. Fifty percent of the scars show decay when they are 4 inches wide (fig. 6). One hundred percent of the scars 7 inches wide or larger are infected.

Not only is the percent of scars with decay related to width of the wound, but the amount (volume) of cull is usually related to the size of the stem scar. The pattern of decay development observed in the sample logs suggests that when fungi become established at scars rot progresses most rapidly longitudinally along the bole and extends radially towards the core of the tree at a much slower rate. Figure 7 presents the amount of cull in board-feet as a function of scar width. Calculation of the regression between these two factors indicated a definite trend. Size of trees and consequent volume of heartwood and the species of fungus causing the cumulative loss were variables that undoubtedly affected the fit of the curve. On the average, about half as much cull will occur at 10-year stem scars as at 20-year scars of the same width.

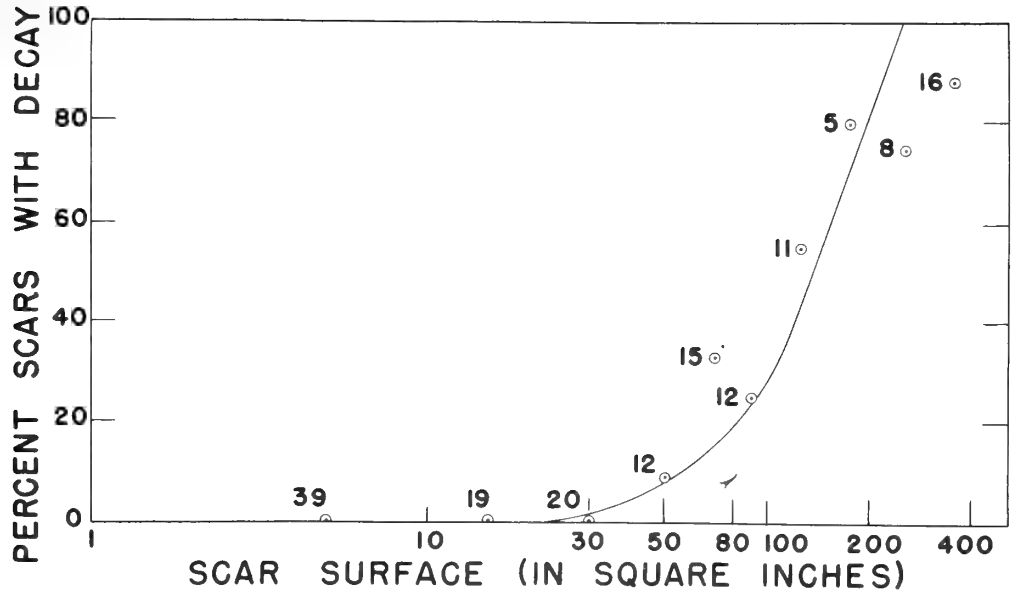

Figure 3.--Relation of scar surface to incidence of decay in 10-year-old stem scars.

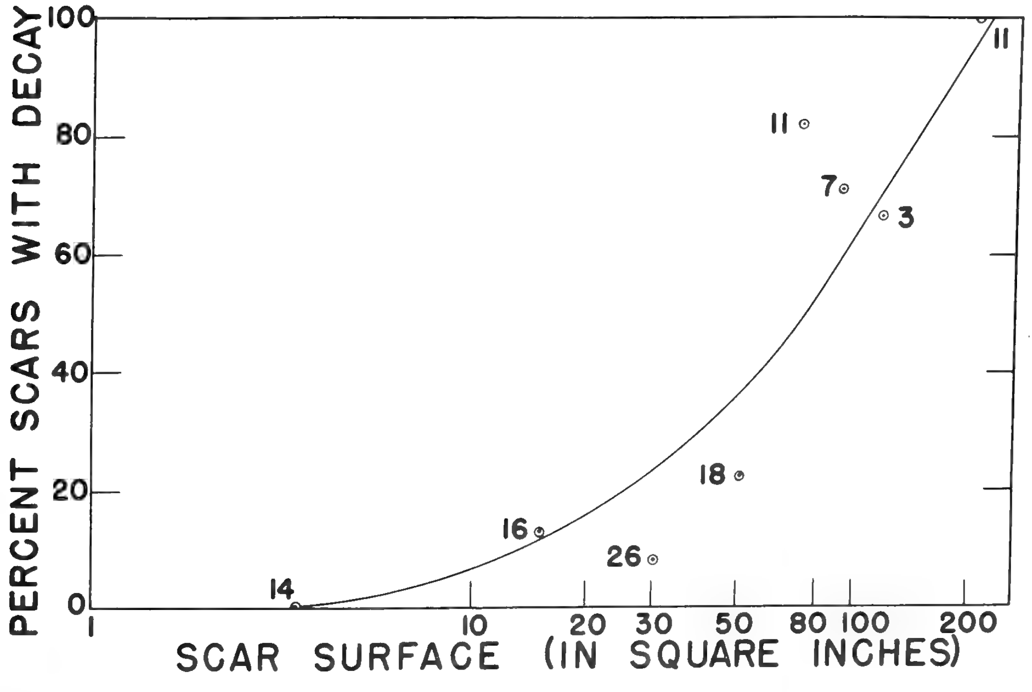

Figure 4.--Relation of scar surface to incidence of decay in 20-year-old stem scars.

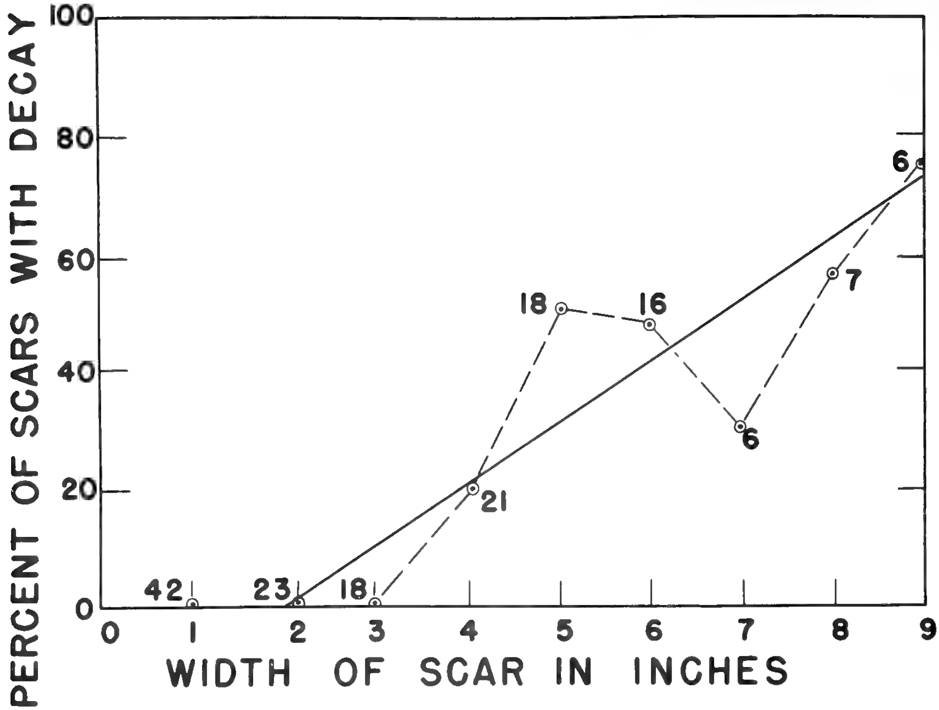

Figure 5.--Relation of scar width to incidence of decay in 10-year-old stem scars.

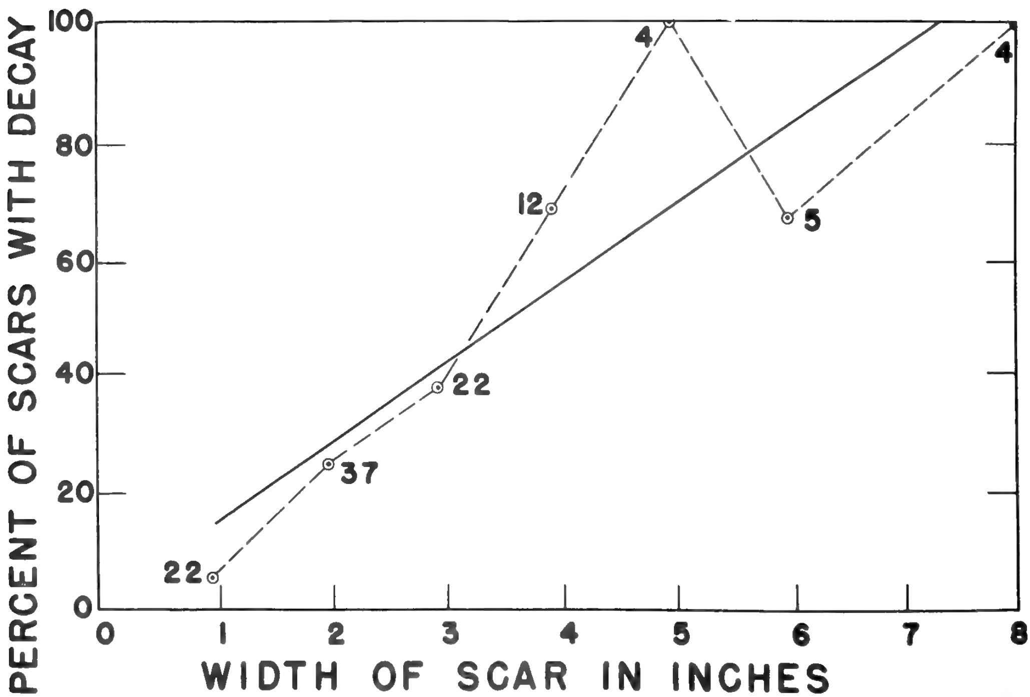

Figure 6.--Relation of scar width to incidence of decay in 20-year-old stem scars.

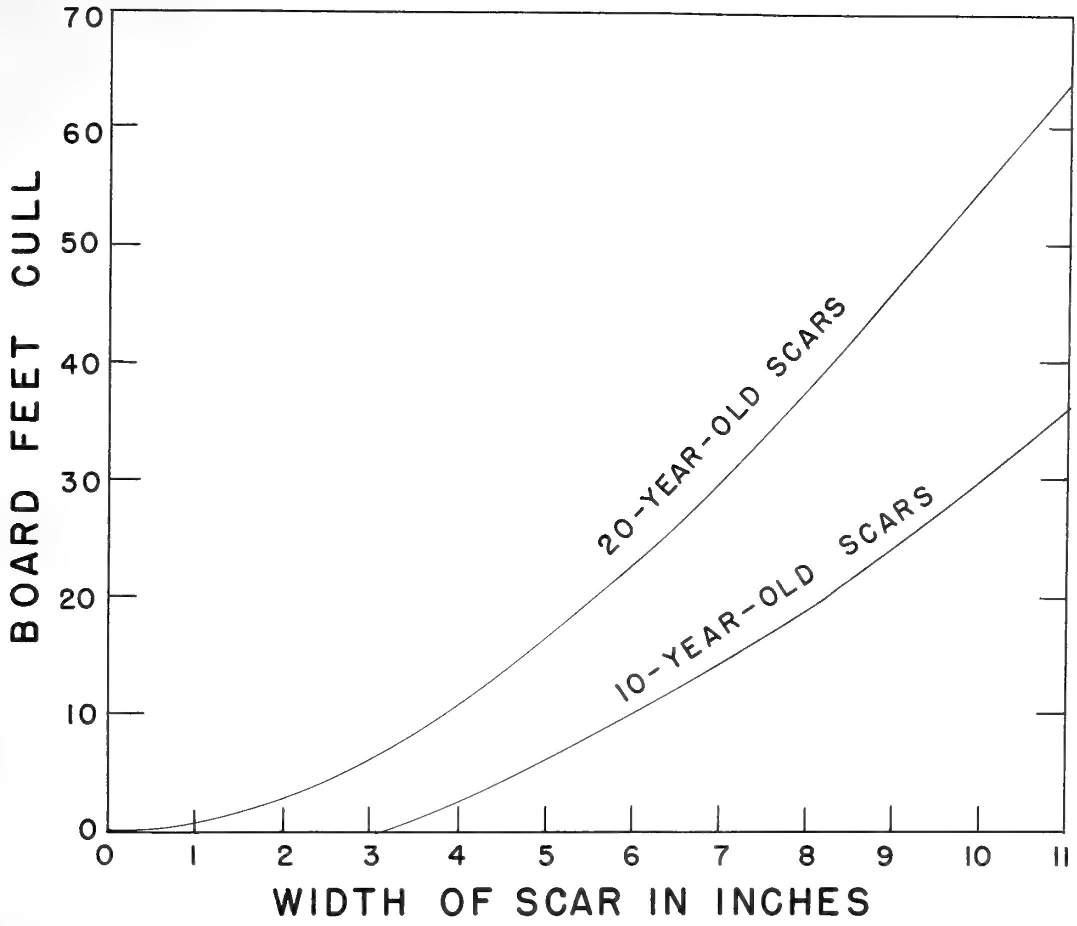

Figure 7.--Relation of scar width to amount of cull in sugar maple sawlogs sampled at the Upper Peninsula Experimental Forest.

Grade Reduction and Value Loss of Sawlogs[16]

Specifications on hardwood log grades for standard lumber (7) were used in determining the quality class of each sawlog dissected.[17] Values were based on local prices in 1954.[18]

16/ The value loss is measured only for the mill logs dissected. It does not reflect the loss in values that resulted from defective tree sections culled in the woods.

17/ All logs dissected at the mill were bucked into 8-foot lengths; therefore, allowance was made in the No. 1 log grade classification for log length.

18/ Prices paid per thousand board-feet, Scribner log scale, for sugar maple sawlogs at local mills (Houghton County, Mich.) during 1954 were: No. 1 grade, $125; No. 2 grade, $55; and No. 3 grade, $38.

Figure 8.--Upper Photo: Fan-shaped discolorations beneath small, callused-over scars extend only toward the heartwood. These dark, brown stains are arrested from progressing outward into the bright callus wood. This is the usual pattern of this defect except in scars infected by sapwood-rotting fungi.
Lower Photo: Small logging scars that have completely healed. Decay is not present and stain is not important since discoloration extended only 11 inches longitudinally as measured after sawn into lumber.

Eleven percent of the gross volume of 5,910 board-feet (Scribner log rule) was degraded when the logs were examined to determine the effects of 10-year-old logging scars on sawlog quality. In this 136-log sample 12 logs (9 percent) were reduced in quality class. Five sawlogs (350 board-feet) were degraded from No. 1 to No. 2 grade, resulting in a loss of $24.60. Six logs (240 board-feet) were lowered from No. 2 to No. 3 grade, a value loss of $6.50. One severely scarred log containing 80 board-feet was reduced from No. 1 to No. 3 grade and lost $7.76 in value. A total loss of $38.86 for the entire sample was computed. This represents an average loss of $6.58 per thousand board-feet of sawlogs.

Ten percent of the gross volume of 5,460 board-feet (Scribner log rule) was degraded when scaled to determine the effect of 20-year-old logging scars on sawlog quality. In the 116-log sample 10 sawlogs (8.6 percent) were degraded. Four logs (290 board-feet) were reduced $20.30 in value when they were degraded from No. 1 to No. 2 grade. Six logs (260 board-feet) were reduced from No. 2 to No. 3 grade, a loss of $7.06. The average loss per thousand board-feet was $5.01.[19]

19/ The lower average loss in value for logs with 20-year-old scars versus that for logs with 10-year-old scars is exceptional. See discussion on page 27.

One intangible loss from logging scars difficult to estimate was encountered in potential veneer logs. As mentioned previously, scars 3 to 4 inches wide on vigorously growing trees usually become covered with healthy callus tissue within 20 years. Beneath the callus growth, however, a fan-shaped, olive-brown discoloration develops and joins with the stain ordinarily referred to as "mineral stain" (17) core so commonly present in Lake States sugar maple (fig. 8). Wood at these areas is similar in color and texture to that of "mineral stain," but the discolorations are restricted to the zone of wood immediately beneath the old logging scar. Discolorations seen at callused-over logging wounds do not advance into the sapwood formed over the wound during the 20-year period following logging injury.

Effect of Logging Scars on Lumber Grade Recovery

A gross volume of 5,300 board-feet (lumber scale) of rough green 4/4 sugar maple lumber from logs with 10-year-old scars was scaled and graded.[20] Defect deductions traced to logging wounds resulted in a decrease of 5 percent in Selects and Better and an 8-percent decrease in No. 1 Common lumber. No. 2 Common boards were increased by 5 percent and No. 3B Common and Mill Cull by 8 percent (table 5).

Table 5.--Comparison of lumber grade recovery for sugar maple sawtimber with two age classes of logging scars. Upper Peninsula Experimental Forest, Michigan.

Lumber grade classification	Volume in board-feet net lumber scale of logs with--			
	10-year-old scars		20-year-old scars	
	With logging scars[1]	Without logging scars[2]	With logging scars[1]	Without logging scars[2]
Selects and Better	620	650	700	710
No. 1 Common	1,750	1,900	1,540	1,640
No. 2 and No. 3A Common	2,250	2,150	1,810	1,780
No. 3B Common and Mill Cull	650	600	1,100	1,050
Total	5,270	5,300	5,150	5,180

1/ True lumber scale.

2/ Scale volumes when the lumber was regraded, assuming defects traced to logging scars were deleted.

20/ In addition, 1,716 board-feet of railroad crossties were produced.

Similarly, a gross volume of 5,180 board-feet (lumber scale) of rough green 4/4 sugar maple lumber from logs with 20-year-old scars was scaled and graded.21/ Defect deductions traced to logging wounds resulted in a 1-percent decrease in Selects and Better and a 6-percent decrease in No. 1 Common lumber. The logging damage caused a 2-percent increase in No. 2 Common and No. 3A Common lumber and a 5-percent increase in No. 3B Common and Mill Cull.

Influence of Wounding on Quality Index

The quality index as outlined by Herrick (12) can also be used to illustrate the influence of logging damage on lumber grade recovery. This index expresses in percentage the product yield of the lumber sawed relative to the dollar value if all boards had been rough green 4/4 No. 1 Common. Broughton's Standard Price List for hardwood lumber was used to establish the average value of the sugar maple lumber.

The lumber actually recovered from the sample logs with 10-year-old scars yielded a quality index of 78.95 percent. A second quality index of 81.77 percent was computed for this lumber, assuming that the defects traced to logging scars were not present. Therefore, defects resulting from 10-year-old logging scars in this sample amounted to a reduction in quality index of 2.82 percent.

True scale and grade of the boards from the sample logs with 20-year-old scars yielded a quality index of 86.47 percent. A second quality index of 88.06 was computed, assuming that the defects traced to logging scars were not present. Thus, defects traced to 20-year-old logging scars amounted to a reduction in quality index of 1.59 percent.

In addition to determination of difference in quality index, actual value of the lumber was computed22/ on the basis of current prices, again using the methods described by Herrick (12). The value of the lumber actually sawed during the study of 10- and 20-year-old logging damage was computed at $906.38. If the defects traced to logging injury had not been present, the value would have been $938.10. Therefore, such defects caused a net loss of $31.72 (3.4 percent of the value) for all the lumber obtained from dissection of all sample logs.

21/ In addition, 1,221 board-feet of railroad crossties were produced.

22/ Net loss in value computed in this section does not include the loss in volume resulting from cull traced to logging scars.

DISCUSSION

For partial-cutting operations in the northern hardwood type, the amount of cull that may develop in reserve maples as a result of logging is an important factor in determining the length of cutting interval. If cuttings are made frequently, the possibilities of logging injuries are increased, and the ultimate cull might well offset some of the advantages of partial cuts. On the other hand, a long interval between cuts may allow decay from logging damage to develop into an economic factor.

It has been reported (6) that northern hardwood stands in Michigan harvested on a 15-year cutting cycle have produced the best economic return on an investment. Since the present investigation shows that the amount of decay at logging scars is significantly related to the age of the wound, the forest manager, in planning the cutting interval, must consider the amount of defect that follows logging injury.

Actually, during a cutting cycle of 10 years only half as much cull developed at logging scars as during an interval of 20 years (fig. 7 on page 19). However, the exact amount of cull not only varies with the time element but also with the width of the wound.[23/] For the 10-year class of scars that were 4 inches wide, only 3 board-feet of defect occurred, but 20 board-feet of cumulative loss, a progressive increase in volume lost through decay, resulted from 8-inch scars.

The increase in amount of decay at scars was obvious in the 20-year cutting interval. There were 11 board-feet of cull at the 4-inch-wide scars and 35 board-feet at the 8-inch scars. These findings establish the amount of cumulative loss that develops at logging scars for 10-year and for 20-year cutting cycles. Although length of scar may influence extent of decay along the bole, the width of scar when related to cull should provide a practical unit of measure for predicting rot following logging damage.

The information obtained relative to the development of rot at 10- and 20-year wounds suggests that the longer the cutting interval, the greater is the risk for accelerated losses. Obviously, unless greater care is used during logging, the number of scars increase with the number of harvest operations. But a comparison of the curves that relate scar size to percent cull shows that a comparatively low percentage of logging injuries become infected by decay-causing fungi within the 10-year period. If scar size encountered in the sample plots and partial-cutting compartments is representative of what might be expected with careful logging, then the length of interval is probably the more important of the two factors, and reducing the cutting interval from 20 years to 15 years is the best practice.

23/ It also varies with the fungus that causes the rot. This part of the study, however, has been largely omitted from this paper.

Frequency of logging scar occurrence on different parts of the tree may be correlated with the amount of either top rot (also called trunk rot) or butt rot. Thus, the distribution of 263 stem scars on the sample trees (fig. 2 on page 13) offers an index of potential decay in the merchantable bole. More than two-thirds of the logging scars occurred on the butt 16-foot log. This section of the tree, when sound, contains the greatest scale volume. Likewise, it often yields the best log grades. Therefore, logging damage to the butt log results in the greatest possible losses.

The applicability of results from this investigation were tested during a cruise of several thousand acres of partially cut northern hardwoods in Michigan's Upper Peninsula and in northern Wisconsin. During this field survey it was determined that fruit bodies of wood-destroying fungi rarely develop on sugar maples at logging scars 10 years or even 20 years old. Furthermore, it was generally recognized that in stands which might be considered to represent average residual volumes of northern hardwoods in the region (3 to 4 thousand board-feet per acre) branch breakage is the less frequent type of logging damage. Too, it was noted that the majority of wounds occurred at the basal part of the trunk--probably attributable to skidding injuries.

The use of scar width as a means of diagnosing the amount of cull, therefore, is much more reliable than the presence of fruiting bodies at the wounds. Scar width alone also proved to be a more useful criterion of the amount of rot for sugar maple than a relation expressed in terms of scar width and circumference of the bole. Width of the wound has been used in estimating decay at scars in oak, yellow-poplar, and basswood in the Appalachians (11) and for injuries to loblolly pine in Alabama (8).

Parabolic curves (fig. 7 on page 19) emphasize that small logging scars (less than 6 inches wide) generally do not result in excessive decay during the first 10-year period. In fact, the data show that rot in sugar maple rarely becomes established within 10 years after logging in scars less than 3 inches wide.

Limb breakage by logging was determined to be highly significant as a cause of top rot in sugar maple. Branch stubs 4 inches in diameter or larger caused a scale deduction in all but 1 of the 20 logs dissected. Defect that developed at large limb stubs 10 years old amounted to about 5 to 8 board-feet of cull. Fifteen to twenty board-feet of decay occurred at the 20-year-old branch stubs.

It is significant, too, that rot rarely becomes established at broken limb scars less than 4 inches in diameter within 10 years or even 20 years after logging. In a sample of 108 small stubs, 97 percent were free of decay and discoloration.

These facts lend themselves to the formulation of tree-risk classes for predicting losses caused by rot (table 6). For example, the data suggest that trees with scars 3 or 4 inches wide may be considered satisfactory risk individuals, since small wounds seldom result in cull in 10 years. But even during this shorter period one may predict that cull will occur at 50 percent or more of the trees with large scars (8 inches or greater in width). These trees must be considered "poor risk" trees and should be harvested at an early time. Also, one can forecast that decay will be present at 50 percent of the logging scars 4 inches wide or larger within the 20-year period. The evidence obtained from dissection of maples with large patches (often several feet long) of bark removed must be stressed. Such large logging scars are most costly and may result in total cull of the tree even within 10 years (fig. 9). These trees should be placed in the highest risk class and must be removed at the time the tree is wounded, since eventual and serious defect is inevitable.

Table 6.--Logging damage risk classification for merchantable sugar maple in the region of the Lake States

Size class of injury	Defect deduction for--	
	10-year-old wounds	20-year-old wounds
	Board-feet 1/	Board-feet 1/
Logging scars 2/		
Smaller than 4 inches wide	No deduction	10
6 inches wide	10	20+
8 inches wide	20	35
10 inches wide	30 to cull	50 to cull
Branch stubs		
Stubs smaller than 4 inches in diameter	No deduction	No deduction
Stubs 4 inches in diameter or larger	5-8	15-20

1/ Log scale.
2/ Decay is seldom present at small scars but becomes prevalent at wounds larger than 6 inches in width.

Care in logging must be emphasized; since demand for prime logs is increasing and logs may be graded for veneer, the presence of any blemish on a log of this particular grade is serious. Thus, a large logging scar 10 years old is just as significant a surface defect to the log buyer as a similar scar of 20 years.

Amount of injury and its relation to cull in the crown likewise make possible the use of tree-risk classification for limb stubs in merchantable sugar maple (table 6).

Figure 9.--Decay traced to large scars on two 12-inch sugar maples. The eventual destruction of severely scarred merchantable trees is inevitable. Upper Photo: Decay at 20-year-old scar. Lower Photo: Rot caused by *Daedalea unicolor* at a 10-year-old scar.

Although the use of tree-risk classes will undoubtedly be helpful for the cruiser or timber marker in estimating trunk defects, the sawmill operator is concerned primarily with the volume and grade yield of lumber from the logs processed. It was established that rot at logging scars in maple progresses rapidly longitudinally but slowly towards the core of the log. Decay in some logs with 10-year-old scars was often "sawed off with the slab" or removed by the edger. No losses from decay resulted in these instances even though wood-destroying fungi were established at the logging scar.

It is possible that certain decay fungi become established during the same season that wounds occur but for several years do not meet with favorable conditions that permit measurable amounts of rot to develop. For example, *Polyporus versicolor* was isolated from a 6-inch-wide logging scar, but this fungus caused no appreciable defect in 10 years. Since it progressed only 2 inches in depth, most of the rot area was removed with the slab when the log was dissected into lumber.

Although the head sawyer may occasionally avoid decay at scars in some logs, it was demonstrated that logging scars (especially 20-year-old wounds) commonly reduce both log scale and log grade. Reduction in scale occurs when logging scar defects are "scaled-out" or deducted from the gross board-foot volume or when sections of trees are culled in the woods as a result of excessive defect (more than 50 percent of the gross log scale in cull). Loss in log quality occurs when surface defects such as logging scars degrade the sawlogs.

Reduction of log grade caused an average loss in value of $6.58 per thousand board-feet in logs with 10-year-old scars versus a loss of only $5.01 per thousand in logs with 20-year-old scars. This gives only a general indication of the magnitude of value losses. More accurate figures with comparable results for the two age classes could be obtained only with a much larger sample where volumes of logs with 10- and 20-year scars are similarly distributed by log grade before damage occurs.

Although about 11,000 board-feet of logs were scaled, graded, and dissected, the distribution of log grades was not adequate since few No. 1 grade logs were in the sample. Nevertheless, these log grade data suggest one change in the standards used in determination of defects in grading Lake States sugar maple sawlogs. Current log grade specifications of the Forest Products Laboratory (7) designate that knots, bark-covered defects such as bumps, overgrown knots, and grub holes, either projecting or recessed, are excluded from clear cuttings. Features such as logging scars, seams, and frost cracks whose maximum depth is one-fifth or less of the diameter of the log at that point, however, are not considered as defects. This is satisfactory for logging scars 3 inches or less in width, which rarely cause decay or discoloration that influence log quality. However, it is recommended that grade classifications for maple sawlogs should designate as defects all logging scars 20 years old that are 4 inches wide or larger, since decay at these large scars often results in degrade of the lumber.

The lumber scale studies show that logging damage causes a measurable loss in lumber grade values. Based on 1954 prices in the Lake States, the net loss in lumber quality for maples with logging scars amounted to $31.72 for the 10,420 board-feet sawed, or a unit loss of about $3.04 per thousand board-feet of lumber produced.

Another added source of loss associated with the effect of logging scars is evident. In both the 10- and 20-year samples defects traced to logging scars in sugar maple caused a reduction of scale in the best lumber grades (Selects and Better and No. 1 Common) and an increase in the lower grades of boards (No. 2 and No. 3 Common) (table 5 on page 21). Since an excess of low-grade lumber is currently being produced, sale of No. 3B grade sugar maple is in a highly competitive market. Therefore, the sawmill operator experiences a loss in sales or in reduction of available working capital because of a large inventory of low-grade lumber.

A comparison of the lumber scale records for boards sawed from maple with 10-year and 20-year scars fails to reveal that considerably more cull occurred at the older wounds in the logs. This is explained by the fact that the log scaler makes deductions for two types of losses not recorded in the lumber tally: (1) Loss in volume when measurable defects are "scaled-out" or deducted from the gross log scale, and (2) total cull of scarred trees in which the only commercial product is "chemical wood" (fig. 9 on page 26).

SUMMARY

1. Comprehensive field investigations were made to determine the rate and amount of decay and degrade in sugar maple (Acer saccharum Marsh.) attributed to fungi which become established at logging scars 10 years and 20 years after partial-cutting operations. The study was made at the Upper Peninsula Experimental Forest, Dukes, Mich., where sample tree records and the history of felling operations were available.

2. Merchantable maples with 10-year and 20-year logging scars were felled and bucked into logs. The nature of the logging wound was described in field records, and the sample logs were scaled and graded. Marked sawlogs were dissected in 4/4 lumber at a mill, and the amount of cull traced to each scar was measured. The sample log number and the defect area traceable to logging scars were placed on each board as it came from the head saw.

3. It was determined that the width of logging scar was the most useful factor in predicting the amount of cull at 10-year-old and 20-year-old trunk scars. On the average, 4-inch-wide scars cause about 3 board-feet of cull in 10 years, but in 20 years a 4-inch scar may have 11 board-feet of decay. Eight-inch-wide scars in 10 years may require a 20-board-foot deduction; whereas in 20 years decay at an 8-inch scar may average as much as 35 board-feet of cull. These data suggest that the amount of cull is associated with width of scar and length of time after the injury occurs.

4. Data from the 252 sample logs (11,370 board-feet, Scribner log rule), sawed to measure defect at 263 logging scars and 128 limb stubs, established that deterioration of sugar maple with logging injuries is related to length of the cutting interval. The facts reported suggest that with care during logging a reduction of the cutting interval from a 20-year period to 15 years will aid in reducing cull percent attributed to logging injury.

5. Tree risk classes for logging scars were developed and were based on the fact that decay is present less frequently at 10-year wounds than at 20-year wounds of the same width. Scars less than 4 inches wide constitute the lowest risk class, since these logging injuries rarely become infected by wood-destroying fungi in 10 years. Fungi were established at only 60 percent of the 8-inch-wide scars in this same 10-year period. But decay was present at 100 percent of the 8-inch-wide logging scars within 20 years, and trees with these large scars are considered poor-risk individuals. Evidence indicates that maples with large patches of bark raked from the trunk are in the highest risk class, since eventual cull of these reserve trees is inevitable.

6. Tree risk classes were also developed from the data on decay at limb stubs. Frayed stubs less than 4 inches in diameter rarely become infected with decay-producing fungi in 20 years. About 95 percent of the broken branches 4 inches in diameter and larger, however, were infected with decay fungi. In 10 years an average of 5 to 8 board-feet of cull can be expected at large stubs (4 inches in diameter and over) and in 20 years cull may amount to 15 to 20 board-feet.

7. Frequency of logging scars on different parts of the tree showed that more than two-thirds of the trunk scars occurred in the butt 16-foot log.

8. Dissection of about 11,000 board-feet of sugar maple sawtimber with 10-year and 20-year scars established that logging damage commonly reduced both log grades and log volumes. An average loss in log grade alone amounted to $6.58 per thousand board-feet of logs with 10-year scars. For 20-year wounds, the loss amounted to $5.01 per thousand board-feet of sawlogs.

9. Marked boards from the numbered logs dissected at the mill were scaled and graded by a certified lumber grader to determine (a) the actual scale and grade of each board, and (b) the scale and grade of the same board by assuming that the defect attributed to the logging scar was not present. Both grades for each board were tallied. The lumber scale records indicated that logging wounds caused an average loss of about $3.04 per thousand board-feet of lumber produced. Furthermore, a larger volume of No. 3B grade boards was recovered from damaged sawlogs. Since this low-grade lumber is in a highly competitive market, loss in sales or loss through reduction of available working capital may result if a large inventory of low-grade boards is produced.

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APPENDICES

Appendix A--Analysis of cull resulting from logging damage for some individual trees.

These analyses illustrate decay types that may follow the more common kinds of logging scars. The photographs, line sketches, and accompanying data for the sample trees and logs will serve as a guide in forecasting cull at logging scars. All logs are 8 feet long. The butt log is identified by the letter A, the log above it by B, etc.

Appendix B--Felled Tree and Sample Log Record forms.

These forms were used to record information on felled sample trees and to describe the wounds on each sample log studied.

Figure 10 (opposite page).--10-year-old logging damage in upper trunk.

(A) Butt end of log B with decay traced to logging scar. A definite pattern of decay development is evident. Width of rot is restricted to the original scar width, and depth of decay seldom extends to the core of the trunk; decay often progresses great distances longitudinally along the bole. An unidentified fungus was isolated from this scar.

(B) Longitudinal section through logs A and B showing the extent of cumulative loss (cross-hatched area).

(C) Board sawed from log B; flaky white rot extended 10 feet in this sugar maple.

Wound Description

Location--multiple scars extending from stump height to 10 feet above the ground; west exposure.
Appearance--5-inch-wide, 45-inch-long scar with open face; three scars in log A.

Decay

Type of rot - - - - - -	white, flaky
Maximum width - - - - -	6 inches
Maximum depth - - - - -	6 inches
Maximum length- - - - -	143 inches

Cull

Computed cull in both logs--33 board-feet (27 percent gross scale).
Cull percent in tree caused by decay at scar--12 percent.

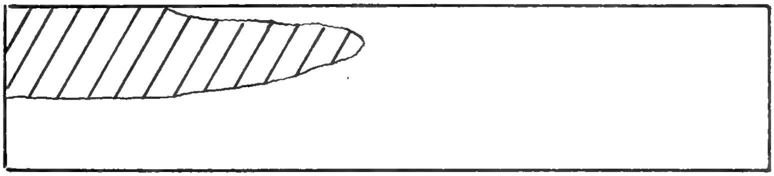
Lumber Grade Recovery

Board-foot measure	Lumber grade	Notes on log value
27	No. 1 Common	Current recoverable value of lumber was $7.24. Computed value of logs was reduced $0.41, and most of this loss occurred in the butt log.
31	No. 2 Common	
27	No. 3A	
5	No. 3B	

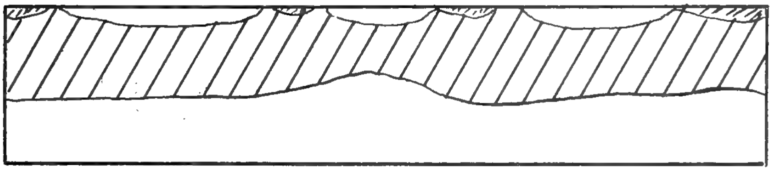
Log Quality Index

Quality index without defect from logging damage	71.8 percent
Quality index with defect from logging damage	67.8 percent
Loss	4.0 percent

(A)



Log B



Log A

(B)

(C)

Figure 11 (opposite page).--10-year-old logging damage in basal trunk.

(A) This bird's-eye veneer butt log was degraded to a No. 2 sawlog as a result of the logging scars illustrated. Polyporus versicolor, the cause of decay, was determined by isolation of the fungus.

(B) Longitudinal section illustrating extent of cumulative loss from decay (cross-hatched area). Most of the rot from this scar was removed with the slab when the log was dissected into lumber. Although decay was present in the sapwood zone, one No. 3 grade crosstie was prepared after "jacket" lumber was sawed.

(C) Board sawed from log; size and location of the two minor defects reduced the grade of this plank from Firsts and Seconds to the Selects grade.

Wound Description

Location--4-inch-wide scar at stump height; 6-inch-wide logging scar 5 feet above ground level; east exposure.
Appearance--wood at both scars exposed; healthy callus tissue at margin; part of wound surface frayed or splintered.

Decay

Type of rot - - - - - -	white, with black lines
Maximum width - - - - -	7 inches
Maximum depth - - - - -	2 inches
Maximum length- - - - -	27 inches

Cull

Computed cull in log--7 board-feet (12 percent gross scale).
Cull percent in tree caused by decay at scar--2.5 percent.

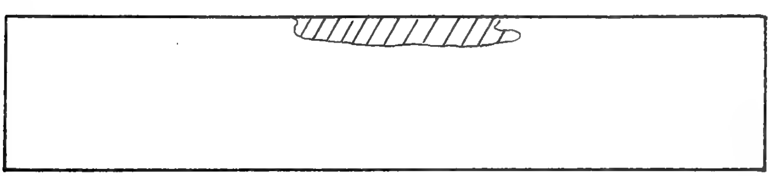
Lumber Grade Recovery

Board-foot measure	Lumber grade	Notes on log value
15	F. A. S.	Current recoverable value of lumber was $11.41. Computed value of log was reduced $0.94.
20	Selects	
8	No. 1 Common	
5	No. 3A	

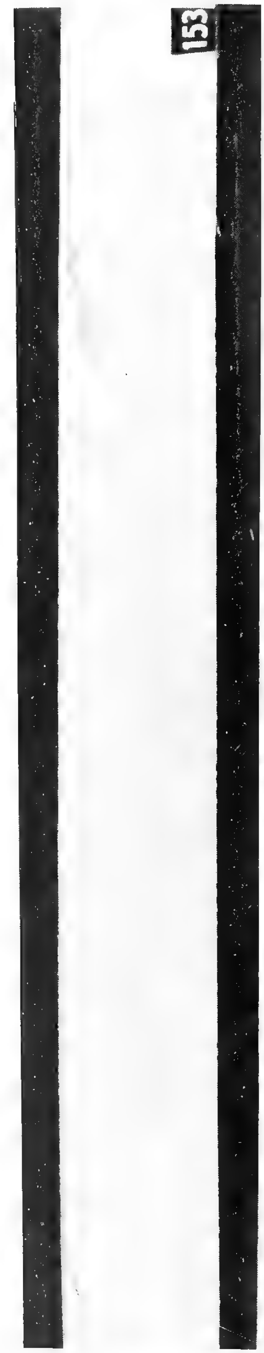
Log Quality Index

Quality index without defect from logging damage	137.8 percent
Quality index with defect from logging damage	127.3 percent
Loss	10.5 percent

(A)



(B)



(C)

Figure 12 (opposite page).--10-year-old logging damage in basal trunk.

(A) Base of sample tree with partly callused scar (above and right of axe).

(B) Longitudinal section illustrating the position of fixed-type defect at logging scar. Fungi rarely infect 3-inch-wide logging scars within 10 years.

(C) Board sawed from log. The plank containing 3 board-feet was degraded from a No. 2 Common to a No. 3A lumber grade as a result of the ingrown bark and fixed, olive-brown discoloration. Ten isolation tests of stained wood at the scar failed to yield a fungus culture.

Wound Description

Location--6 feet above the ground; north exposure.
Appearance--3-inch-wide, 8-inch-long logging wound; healthy callus tissue at margin.

Decay

None.

Cull

No cull.
Discoloration fixed to original scar area; olive-brown stain was restricted to zone one-fourth inch in depth.

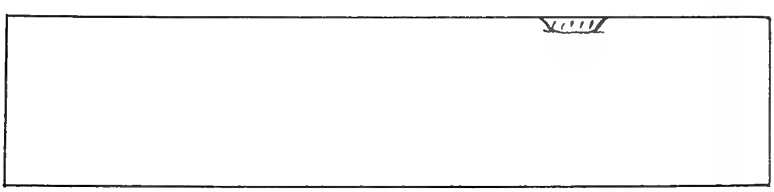
Lumber Grade Recovery

Board-foot measure	Lumber grade	Notes on log value
5	F. A. S.	Current recoverable value of lumber was $7.89. Computed value of log was reduced $0.13.
60	No. 1 Common	
3	No. 3A	
4	No. 3B	

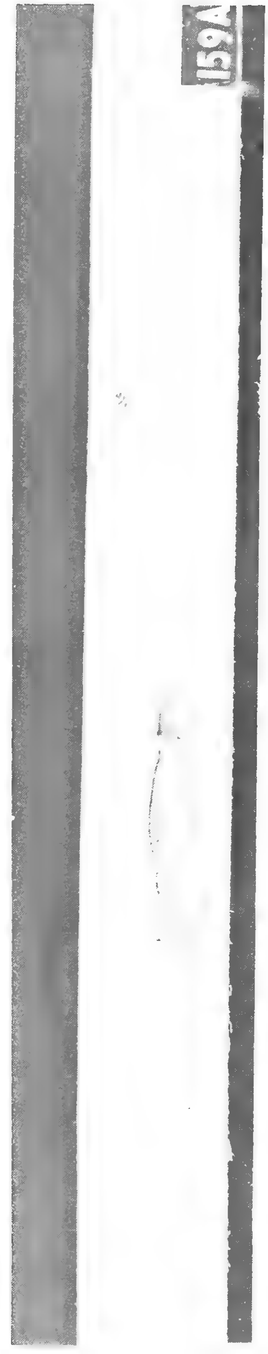
Log Quality Index

Quality index without defect from logging damage	99.5 percent
Quality index with defect from logging damage	97.9 percent
Loss	1.6 percent

(A)



(B)



(C)

Figure 13 (opposite page).--10-year-old logging damage at limb stub.

(A) Butt end of log D with decay traced to 4-inch-diameter limb scar. Breakage of large branches flush with the bole provides an immediate infection court for decay fungi. Immature fruiting bodies of Daedalea unicolor are present, and this fungus was isolated from decay at the limb stub.

(B) Longitudinal section through logs C and D showing the extent of cumulative loss from decay (cross-hatched area). Rot had progressed more rapidly in the heartwood; sapwood decay advances at a retarded rate.

(C) Board sawed from log; white decay extended 46 inches above the branch scar.

Wound Description

Location--27 feet above ground; east exposure.
Appearance--4-inch-diameter broken branch, stub removed flush with trunk; numerous immature fruiting bodies of Daedalea unicolor at limb scar; these small conks were not apparent from ground.

Decay

Type of rot - - - - - -	white
Maximum width - - - - -	6 inches
Maximum depth - - - - -	5 inches
Maximum length- - - - -	91 inches

Cull

Computed cull in logs--21 board-feet.
Cull percent in tree caused by decay at scar--21 percent.

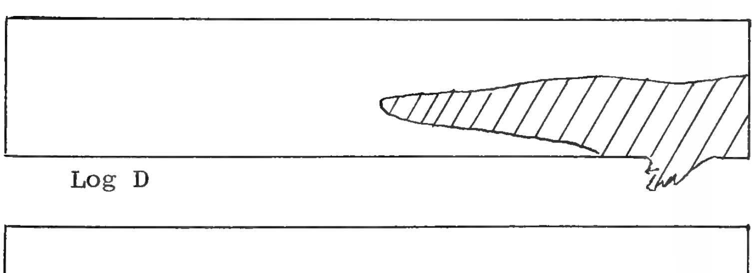
Lumber Grade Recovery

Board-foot measure	Lumber grade	Notes on log value
8	No. 2 Common	Current recoverable value of lumber was $1.56. Computed value of log was reduced $0.30. In addition, one log was not suitable for use as crosstie since it contained excessive rot.
3	No. 3A	
19	No. 3B	

Log Quality Index

Quality index without defect from logging damage	55.5 percent
Quality index with defect from logging damage	46.4 percent
Loss	9.1 percent

(A)



(B)

(C)

Figure 14 (opposite page).--10-year-old logging damage at limb stub.

(A) Frayed stub of 4-inch-diameter branch on sample log C. Field observations indicate that during the first 10-year exposure period rot fungi seldom become established within the "right cylinder" of logs with 2-foot-long frayed stubs.

(B) Longitudinal section through log. Neither decay nor stain entered the log.

(C) Board sawed from log. The only surface defect in the lumber was the large sound knot.

Wound Description

Location--18 feet above ground; southwest exposure.
Appearance--4-inch-diameter broken branch with 19-inch-long frayed stub which projected upwards.

Decay

None.

Cull

No loss attributed to logging damage.

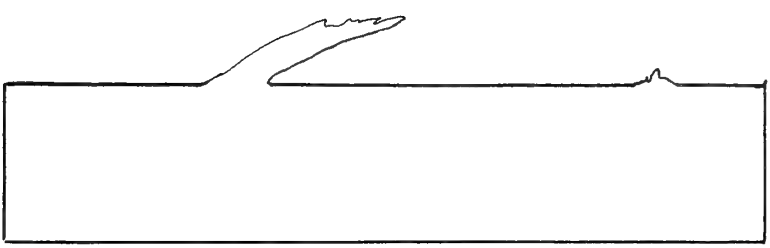
Lumber Grade Recovery

Board-foot measure	Lumber grade	Notes on log value
3	No. 2 Common	Current recoverable value of lumber was $0.72. There was no reduction of log value associated with branch breakage.
6	No. 3A	
4	No. 3B	

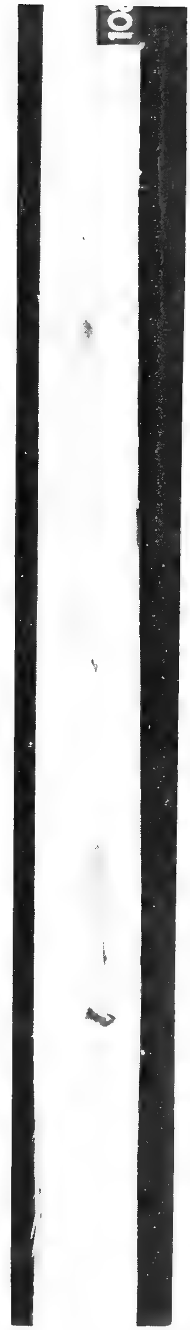
Log Quality Index

Quality index without defect from logging damage	49.2 percent
Quality index with defect from logging damage	49.2 percent
Loss	0.0 percent

(A)



(B)



(C)

Figure 15 (opposite page).--20-year-old logging damage in upper trunk.

(A) Butt end of log B bucked from sample plot tree. The original tree description dated June 16, 1931, indicated the scar occurred during logging. Corticium vellereum was isolated from this scar.

(B) Longitudinal section illustrating extent of cumulative loss from decay (cross-hatched area). Since rot beneath the healed scar (log in foreground) did not extend to either end, the cull was "hidden" in the log.

(C) Board sawed from log. White rot in the plank extended to within 4 inches of the end, but decay traced to the logging scar was not apparent until dissection of the log at the mill. Six boards containing 27 board-feet were affected by rot; average cull was 9 percent per board.

Wound Description

Location--4-inch-wide scar at 12 feet above ground; southwest exposure.
Appearance--healed, smooth callus growth.

Decay

Type of rot - - - - - -	white
Maximum width - - - - -	3 inches
Maximum depth - - - - -	5 inches
Maximum length- - - - -	42 inches

Cull

Computed cull in log--6 board-feet (15 percent gross scale).
Cull percent in tree caused by decay at scar--3.7 percent.

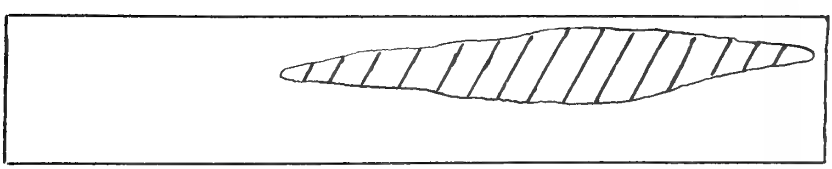
Lumber Grade Recovery

Board-foot measure	Lumber grade	Notes on log value
23	No. 1 Common	Current recoverable value of lumber was $3.66. Computed value of log was reduced $0.27.
5	No. 2 Common	
4	No. 3A	
12	No. 3B	

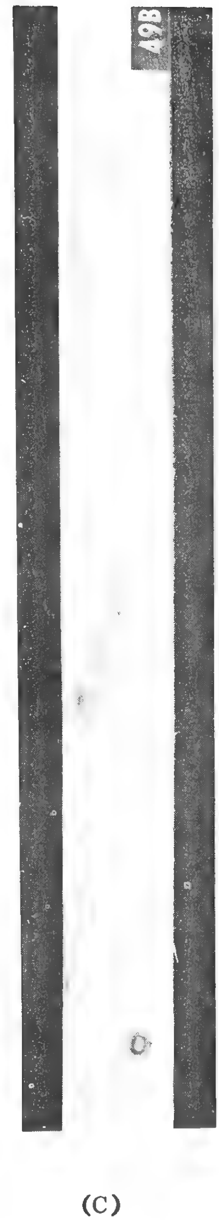
Log Quality Index

Quality index without defect from logging damage	79.7 percent
Quality index with defect from logging damage	74.3 percent
Loss	5.4 percent

(A)



(B)



(C)

Figure 16 (opposite page).--20-year-old logging damage in upper trunk.

(A) A dark brown slime-flux area was evident on the bark at the base of the wound to the right of scale stick.

(B) Longitudinal section illustrating extent of cumulative loss from decay (cross-hatched area).

(C) Board sawed from log. Decay zone was restricted to the heartwood which was discolored by mineral stain.

Wound Description

Location--16 feet above ground; northwest exposure.
Appearance--original scar was 9 inches long and 5 inches wide; open seam formed by callus growth which covered the wound; scar surface appeared well-drained; dark brown slime-flux area was evident at the base of the scar.

Decay

Type of rot - - - - - -	white
Maximum width - - - - -	2 inches
Maximum depth - - - - -	2 inches
Maximum length- - - - -	26 inches

Cull

Computed cull in log--2 board-feet (7 percent gross scale).
Cull percent in tree caused by decay at scar--3.5 percent.

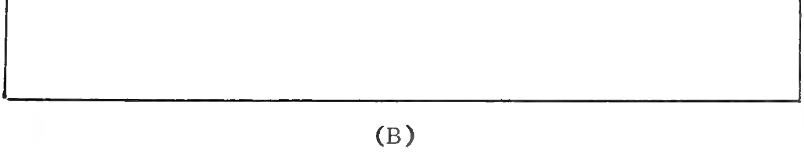
Lumber Grade Recovery

Board-foot measure	Lumber grade	Notes on log value
6	No. 1 Common	Extensive mineral stain and center rot which was not traced to the logging scar resulted in degrade of much lumber. Current recoverable value of lumber was $1.09.
3	No. 3A	
7	No. 3B	
16	Below grade	

Log Quality Index

Quality index without defect from logging damage	32.3 percent
Quality index with defect from logging damage	32.3 percent
Loss	0.0 percent

(A)



(B)

(C)

Figure 17 (opposite page).--20-year-old logging damage in upper trunk.

(A) End of log from leaning, 18-inch sugar maple. Decay was evident at the exposed part of the wound. It is apparent that leaning trees are more subject to severe damage than are upright trees.

(B) Longitudinal section illustrating extent of cumulative loss from decay traced to logging scar (cross-hatched area).

(C) Plank sawed from log C; decay affected an average of 15 percent of the board surface on 44 board-feet of lumber sawed from this log.

Wound Description

Location--28 feet above ground; south exposure.
Appearance--original scar was 46 inches long and 3 inches wide; upper part of the wound callused over, but basal area remained exposed; this basal area of scar was cup-shaped and capable of retaining moisture.

Decay

Type of rot - - - - - -	white, with black lines
Maximum width - - - - -	7 inches
Maximum depth - - - - -	13 inches
Maximum length- - - - -	77 inches

Cull

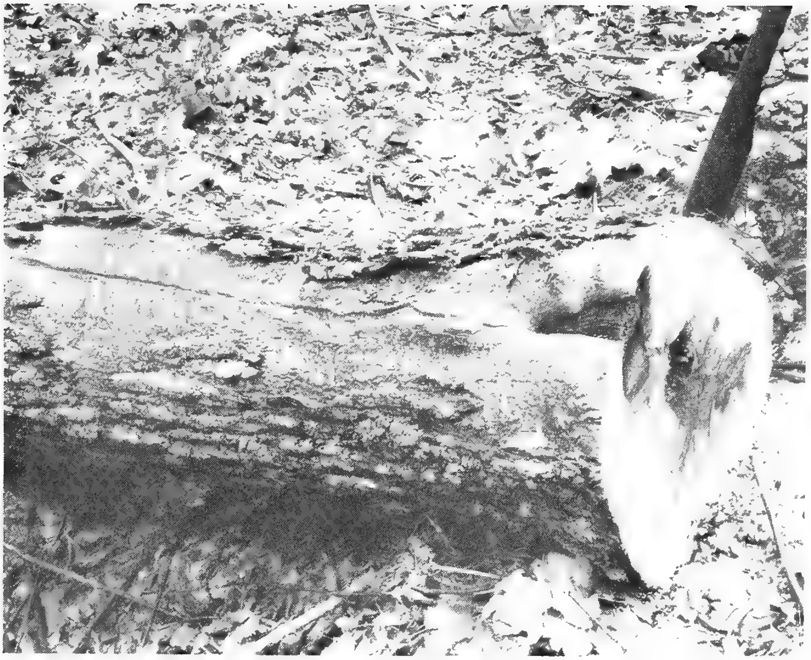
Computed cull in two logs affected--31 board-feet (34 percent of gross log scale).
Cull percent in tree caused by decay traced to scar--13 percent.

Lumber Grade Recovery

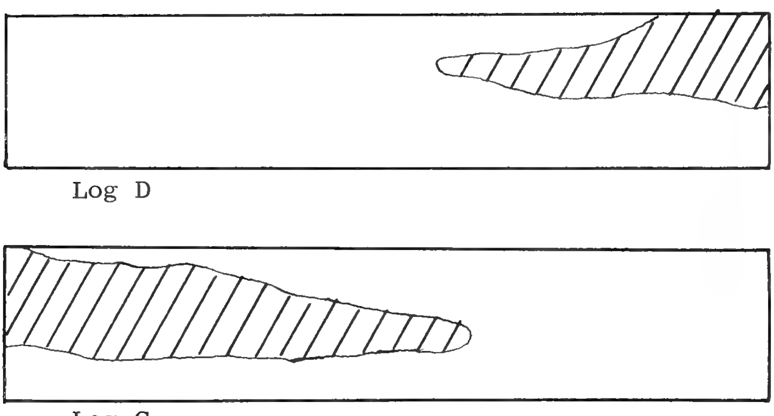
Board-foot measure	Lumber grade	Notes on log value
20	No. 1 Common	Current value of logs C and D in
9	No. 2 Common	recoverable lumber was $6.92.
5	No. 3A	Computed value of these logs if
25	No. 3B	damage had been avoided was $7.75.

Log Quality Index

Quality index without defect from logging damage	70.0 percent
Quality index with defect from logging damage	62.2 percent
Loss	7.8 percent



(A)



(B)

(C)

Figure 18 (opposite page).--20-year-old logging damage to basal trunk.

(A) Base of tree showing callus tissue on 4-inch-wide logging scar. The 8-foot butt log scaled 40 board-feet, but it was not degraded since the scar was located at the end of the bolt.

(B) Longitudinal section through log showing extent of cumulative loss from decay (cross-hatched area).

(C) Board sawed from log; decay extended 4 feet along the log and affected 14 percent of the surface of 10 board-feet of lumber.

Wound Description

Location--stump height.
Appearance--open seam formed by callus growth; wound surface well-drained; north exposure.

Decay

Type of rot - - - - - -	white
Maximum width - - - - -	7 inches
Maximum depth - - - - -	7 inches
Maximum height- - - - -	48 inches

Cull

Computed cull in log--10 board-feet (25 percent gross scale).
Cull percent in tree caused by decay at scar--3.5 percent.

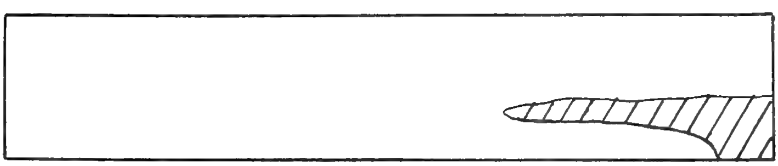
Lumber Grade Recovery

Board-foot measure	Lumber grade	Notes on log value
20	No. 1 Common	Current log value in recoverable lumber $3.77. Computed value of log was reduced $0.18.
12	No. 2 Common	
12	No. 3B	

Log Quality Index

Quality index without defect from logging damage	76.6 percent
Quality index with defect from logging damage	73.0 percent
Loss	3.6 percent

(A)



(B)

(C)

Figure 19 (opposite page).--20-year-old logging damage in basal trunk.

(A) Large sugar maple with three basal logging scars. Fruiting bodies of *Daedalea unicolor* occurred near the scar, and this fungus was isolated from decay at the scar.

(B) Butt of 26-inch maple with scar areas at upper right of log. Extensive decay had developed in the heartwood and in the sapwood.

(C) Longitudinal section through butt log showing extent of cumulative loss from decay (cross-hatched area). Half of the log which contained 140 board-feet gross scale was defective; much of the remaining lumber was degraded.

(D) Board sawed from the butt log; white decay in this plank extended 7 feet, 3 inches.

Wound Description

Location--9-inch-wide scar at ground level, 4-inch-wide scar at stump height, 6-inch-wide scar at breast height; all injuries with north exposure.
Appearance--fruiting bodies present, exposed wood blackened, soft.

Decay

Type of rot - - - - - -	white
Maximum width - - - - -	14 inches
Maximum depth - - - - -	9 inches
Maximum length- - - - -	87 inches

Cull

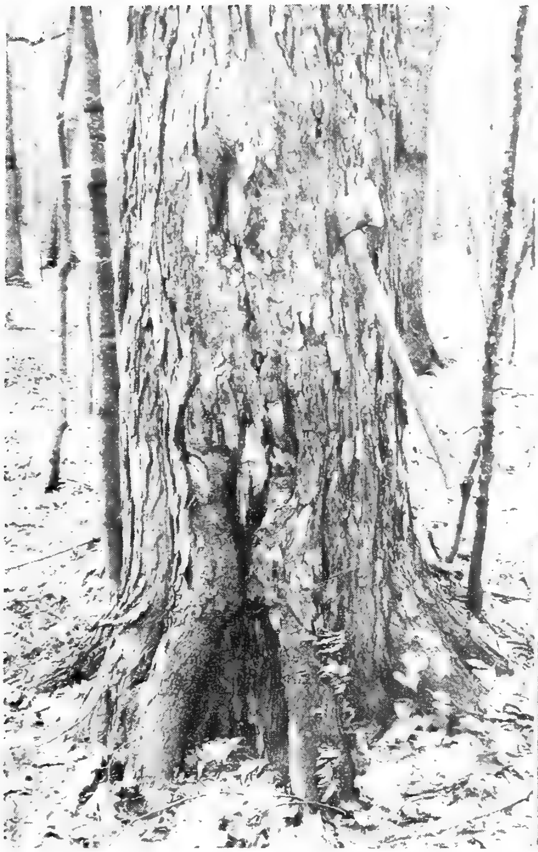
Computed cull in log--70 board-feet (50 percent gross scale).
Cull percent in tree caused by decay at scar--11 percent.

Lumber Grade Recovery

Board-foot measure	Lumber grade	Notes on log value
26	F. A. S.	Current recoverable value of lumber was $7.79. Computed value of log was reduced $2.13. In addition, about 70 board-feet of lumber were mill cull.
26	No. 1 Common	
7	No. 2 Common	
18	Below grade	

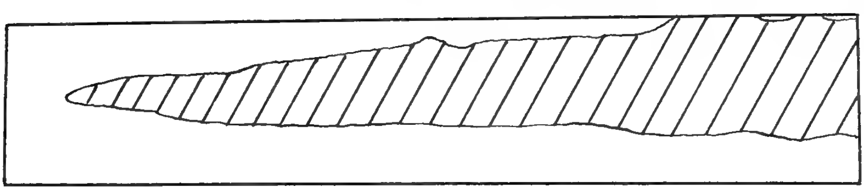
Log Quality Index

Quality index without defect from logging damage	115.2 percent
Quality index with defect from logging damage	90.4 percent
Loss	24.8 percent



(A)

(B)



(C)

(D)

FELLED TREE RECORD

Field Form 1

Date ____________

____

Tree Number ____ P. S. P. No. ____

Compartment No. ______

Tree species ________

D. B. H. ________ inches

Merch. Ht. ________ logs

Forest products:

Veneer __________ Bd. Ft.
2 logs ________ Bd. Ft.
3 logs ________ Bd. Ft.
Chem. Bolts ______ Bd. Ft.

Log Sample No. ________
Log Sample No. ________
Log Sample No. ________
Log Sample No. ________

Photograph numbers: ______________ in film pack No. ____

If injury resulted in degrade of logs, give reason and extent of degrade for each log (see Sample Log Form).

Degrade From	Degrade To	Log Volume	Reason for Degrade

TYPE OF LOGGING INJURY

Wound or Scar

(Sketch tree on reverse side and indicate size, number and location of wounds.)

Broken Limbs

(Sketch tree crown on reverse side and indicate size, number and location of broken limbs.)

Scar No.	Description of external signs of decay.	Limb No.	Description of external signs of decay.

FELLED TREE RECORD

(Page 2)

SCARS AND WOUNDS

a. Sketch approximate size and location of scar. Indicate orientation by N, S, E, or W.

b. Identify scar by number, 1, 2, 3.

BROKEN LIMBS

a. Sketch crown and approximate size and location of broken limbs.

b. Identify stub location by a, b, c.

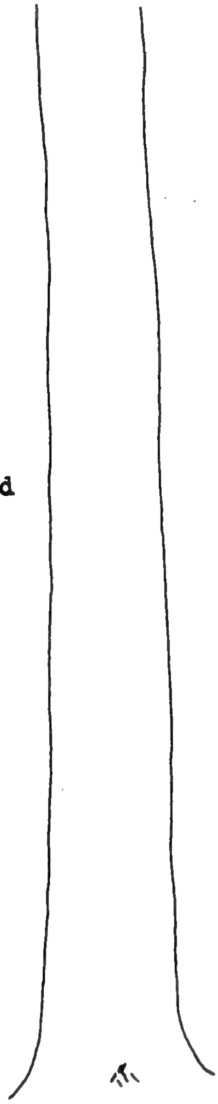
c. Indicate nature of stub as smooth end, frayed end.

Limit of merchantability

Indicate sample log numbers to be dissected at the mill; show log length, d.i.b. and d.o.b.

Height - six feet

Root Collar - 18"



Sample Log Record

Field Form 2

Date ____________________

____________________ (Observer)

Tree Number _____ P. S. P. No. _____

Compartment No. __________ Photo of Log _______

Log Number __________

Class of Logging Injury (Broken Limb, Basal Scar, Upper Scar)
(Conducive, Non-conducive)

d.i.b. _______ d.o.b. _____ Log Length ______________ feet

Forest Products
Lab. Log Grade ___

(Small end of Log)

(Log Faces)

Diam. of decay or discoloration apparent at each end of log.

Top end

Butt end.

Detailed description of wounds: ______________________________

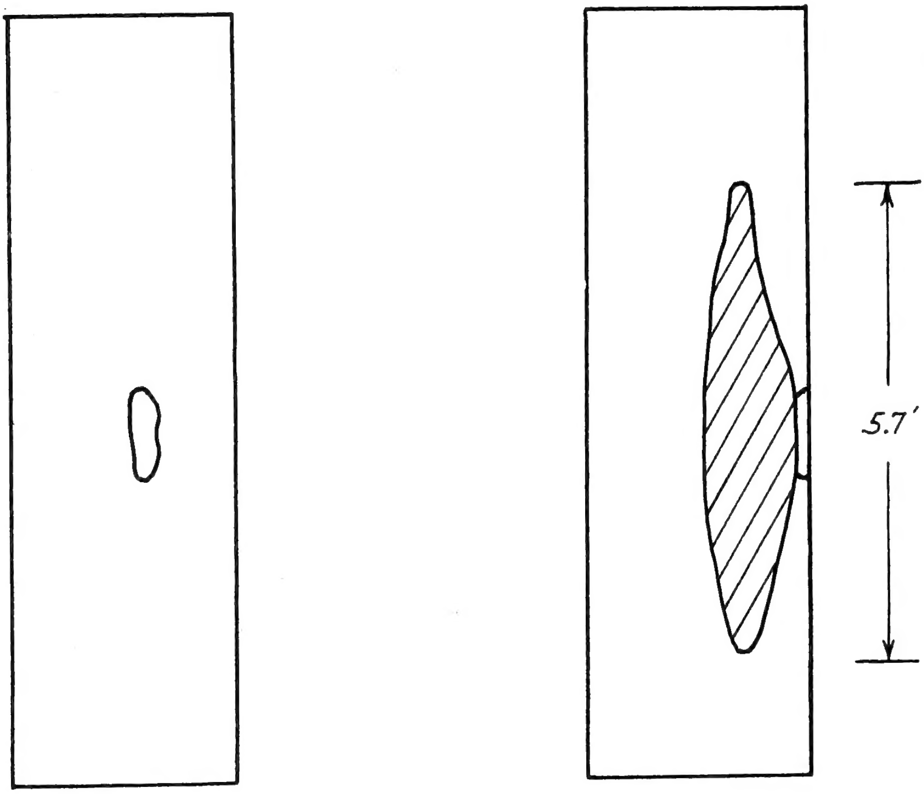
____

____

____

Sample Log Record
(Page 2)

Used in recording cull as illustrated below



Face view

Side view

Longitudinal section
through scar area

Depth into heartwood - - - - 7"
Maximum scar width - - - - - 5"
Type of decay: white rot
Computed loss in volume* - -

$$\frac{5.7 \times 8 \times 6}{15} = 18 \text{ board-feet}$$

*An inch was added to the dimensions of decay width and of thickness (decay depth into heartwood) as a safety factor to insure including all of the cull volume. See footnote 13 on page 11 for formula.

SOME RECENT STATION PAPERS

Guide for Selecting Superior Forest Trees and Stands in the Lake States.
P. O. Rudolf.
Station Paper 40, 32 pp., illus. 1956.

Chemical Control of Brush and Trees in the Lake States.
P. O. Rudolf and Richard C. Watt.
Station Paper 41, 58 pp., illus. 1956.

The Forest Insect and Disease Situation, Lake States, 1956.
L. C. Beckwith and R. L. Anderson.
Station Paper 42, 26 pp., illus. 1956.

Wood Pallets in the Minneapolis-St. Paul Area: An Outlet for Low-Grade Hardwoods.
John R. Warner and D. R. Cowan.
Station Paper 43, 34 pp., illus. 1956.

Silvical Characteristics of Red Pine.
Paul O. Rudolf.
Station Paper 44, 32 pp., illus. 1957.

Silvical Characteristics of Black Spruce.
M. L. Heinselman.
Station Paper 45, 30 pp., illus. 1957.

The Market for Domestic Charcoal in Wisconsin.
John R. Warner and William B. Lord.
Station Paper 46, 15 pp., illus. 1957.

Silvical Characteristics of Rock Elm.
Harold F. Scholz.
Station Paper 47, 16 pp., illus. 1957.

Natural Regeneration on a 2-Acre Mixed-Oak Clear Cutting Five Years After Logging.
Harold F. Scholz, and A. J. DeVriend.
Station Paper 48, 11 pp., illus. 1957.

Silvical Characteristics of Quaking Aspen.
R. O. Strothmann and Z. A. Zasada.
Station Paper 49, 26 pp., illus. 1957.

Silvical Characteristics of Sugar Maple.
R. M. Godman.
Station Paper 50, 24 pp., illus. 1957.